APPENDIX D2

NUTRIENT ASSESSMENT PROTOCOL FOR LAKES AND RESERVOIRS

NEW MEXICO ENVIRONMENT DEPARTMENT
SURFACE WATER QUALITY BUREAU

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Purpose and Applicability

Nutrient impairment occurs when algae and other aquatic vegetation (macrophytes) interfere with designated uses such as contact recreation, domestic water supply, or coldwater aquatic life. Excess amounts of nitrogen and phosphorus can cause undesirable aquatic life (e.g. community composition shifts or toxic algal blooms) and/or result in a dominance of nuisance species (e.g. excessive and/or unsightly algal mats or surface plankton scums). Excessive algal growth may cause anaerobic conditions resulting in fish kills or loss of sensitive species.

With the recognition of the pervasiveness and potential severity of nutrient-related problems comes the need to accurately monitor and assess nutrient impairment. This document establishes an assessment protocol for determining the nutrient impairment status of lakes and reservoirs. While a few lakes have segment specific numeric criteria for total phosphorus, New Mexico currently has no general numeric criteria for nutrients. The narrative criterion in *State of New Mexico Standards for Interstate and Intrastate Surface Waters* found at 20.6.4.13 NMAC (available at: http://www.nmenv.state.nm.us/swqb/Standards/) states:

> *Plant nutrients from other than natural causes shall not be present in concentrations which will produce undesirable aquatic life or result in a dominance of nuisance species in surface waters of the state.*

This document will be used to determine if a lake or reservoir is meeting the narrative criterion. Impairment threshold values are used to translate the narrative criterion into quantifiable endpoints. Threshold values are derived from water quality standards, SWQB analyses of existing data, or published literature. For lakes and reservoirs, nutrient enrichment indicators (e.g., TP, TN, chlorophyll *a*, etc.) are compared to threshold values to determine impairment. To address the "*from other than natural causes*" portion of the criterion, designated or assigned aquatic life use is used to classify sites in order to define reference conditions that account for New Mexico's complex landscape and high biodiversity. If a waterbody is determined to be impaired, it will be added to the Integrated Clean Water Act §303(d)/§305(b) List of Assessed Waters (Integrated List) as impaired.

This protocol is a dynamic document and subject to refinement as more data are collected and analyzed, enabling more precise classification of lentic systems and clearer definition of the relationships between nutrient concentrations, indicators, and impairments of New Mexico lakes and reservoirs. In the event that new data indicate that the threshold values presented in this document are inaccurate and/or if new standards are adopted, the threshold values will be adjusted accordingly.

This protocol is not applicable to the following water body types:

- Playas
- Large rivers (non wadeable)
- Perennial, wadeable streams
- Intermittent streams which includes water bodies under 20.6.4.98 or 20.6.4.128 NMAC
- Ephemeral streams which includes water bodies under 20.6.4.97 or 20.6.4.128 NMAC
- Wetlands

This assessment procedure uses samples and measurements taken at the deep station only, which is the water quality monitoring station established at the deepest portion of the lake (usually near the dam in reservoirs). In addition, the full suite of parameters must be monitored to use this assessment protocol (see Section 3.0 for more information).

A separate nutrient assessment protocol for perennial, wadeable streams is available at: http://www.nmenv.state.nm.us/swqb/protocols/. Additional information on nutrient threshold development is available on SWQB's website at: http://www.nmenv.state.nm.us/swqb/Nutrients/.

1.0 Introduction/Background

The presence of some aquatic vegetation is normal in lakes and reservoirs. Algae and macrophytes provide habitat and food for other aquatic organisms. However, excessive aquatic vegetation is not beneficial to most aquatic life and may change the associated community structure. High nutrient concentrations may promote an overabundance of algae and floating or rooted macrophytes. The types and amounts of aquatic vegetation often reflect the level of nutrient enrichment. Algae are either the direct (excessive periphyton mats or surface plankton scums) or indirect (diurnal swings of dissolved oxygen and pH as well as high turbidity) cause of most problems related to excessive nutrient enrichment. In addition, algal blooms can cause taste and odor problems in drinking water supplies. One of the most expensive problems caused by nutrient enrichment is increased treatment required for drinking water. Blooms of certain types of blue-green (cyanobacteria) and golden (*Prymnesium* spp.) algae can produce toxins that are detrimental to fisheries in addition to animal and human health.

Limited increases in primary productivity (e.g. aquatic plants or algae) can increase the abundance of aquatic life such as invertebrates and fish in lakes and reservoirs. However, excessive plant growth and subsequent decomposition can limit aquatic populations by decreasing dissolved oxygen (DO) concentrations as plant respiration and decomposition of dead vegetation consumes DO. Lack of DO stresses aquatic organisms and can cause fish kills; even relatively small reductions in DO can have adverse effects on both invertebrate and fish communities. Nocturnal respiration can cause oxygen depletion in waters with high primary productivity and low aeration rates. Development of anaerobic conditions due to oxygen depletion alters a wide range of chemical equilibria, may mobilize certain pollutants, and generates noxious odors (USEPA 1991).

The variables referred to in this document are measurable water quality parameters that can be used to evaluate the degree of eutrophication in lakes and reservoirs. The parameters consist of <u>causal</u> variables (total nitrogen [TN] and total phosphorus [TP] concentrations) and <u>response</u> variables (algal biomass, DO concentration, and Secchi depth). The typically large watershed-to-lake size ratio of many impoundments in arid landscapes can have great influence on both nutrient loading and biomass production. Additionally, low and middle elevation lakes and reservoirs in New Mexico may have naturally high levels of productivity due to nutrient loading, long growing seasons, and high temperatures. Many other factors come into play in lentic systems, including size and depth of the lake, residence time of the water, and geology of the surrounding area. Additional factors will be noted during monitoring to aid in interpretation of measured variables.

Available information does not allow identification of definitive and broadly-applicable water quality thresholds beyond which a particular designated use is always impaired in all water bodies. For the most part, nutrient-related impacts are gradational rather than characterized by sharp transitions. Furthermore, lakes and reservoirs are complex biogeochemical systems subject to many site-specific factors that affect responses to nutrient loading. Another challenge is the relatively small number of studies designed to identify nutrient-related thresholds of designated use impairment. Despite these challenges, the basic relationship between nutrient enrichment and use impairment in these water bodies is recognized.

2.0 Development of the Numeric Thresholds

This assessment approach considers multiple lines of evidence to make a final impairment determination. The abundance of confounding factors and indirect and fluctuating nature of the relationships between these factors make the use of a single variable for assessment challenging. Because of this, a suite of indicators is used in a weight-of-evidence approach to provide a more comprehensive and defensible assessment. The nutrient assessment is based on quantitative measures of both causal and response variables (USEPA 2010).

Aquatic life uses (i.e., coldwater, warmwater) are defined by water temperatures and other characteristics that are known to support the growth or propagation of certain aquatic species. Assessment of the DO indicator is dependent upon the designated aquatic life use, associated numeric criteria, and established procedures for assessing DO. For assessment of the other indicators (i.e., TN, TP, algal biomass, and Secchi depth), New Mexico's lakes and reservoirs are grouped into three categories based on their designated aquatic life use or assigned lake type. The lake goups include: (1) coldwater (COLD), (2) warm water (WARM), and (3) sinkholes (SINKHOLES). All reservoirs and high-elevation lakes with high quality coldwater aquatic life (HQCWAL) or coldwater aquatic life (CWAL) designated uses are assigned to the COLD group, while those with marginal CWAL, warmwater aquatic life (WWAL), or marginal WWAL designated uses are assigned to the WARM group. Sinkhole lakes are classified separately from other lakes and reservoirs because they are groundwater-fed, which results in unique chemical properties, and, in general, they are more influenced by the surrounding geology than adjacent land use.

Some lakes do not fit directly into one of the three lake groups. Coolwater aquatic life use was not in effect when data analysis and threshold development for this assessment protocol occurred. There are currently seven reservoirs that are designated in the standards with a coolwater aquatic life use. There are also six lakes with dual WWAL and CWAL designated uses. Given that these lakes do not fit directly into one lake group, lakes and reservoirs with coolwater or dual CWAL/WWAL uses were assigned a lake group based on the dominant fish community in the water body. The dominant fish community for these lakes was determined by examining fish community composition data and/or discussions with New Mexico Department of Game and Fish personnel. Figure 1 contains a generalized flowchart for assigning the appropriate lake group. Table 1 indicates the lake group assignments for these water bodies.

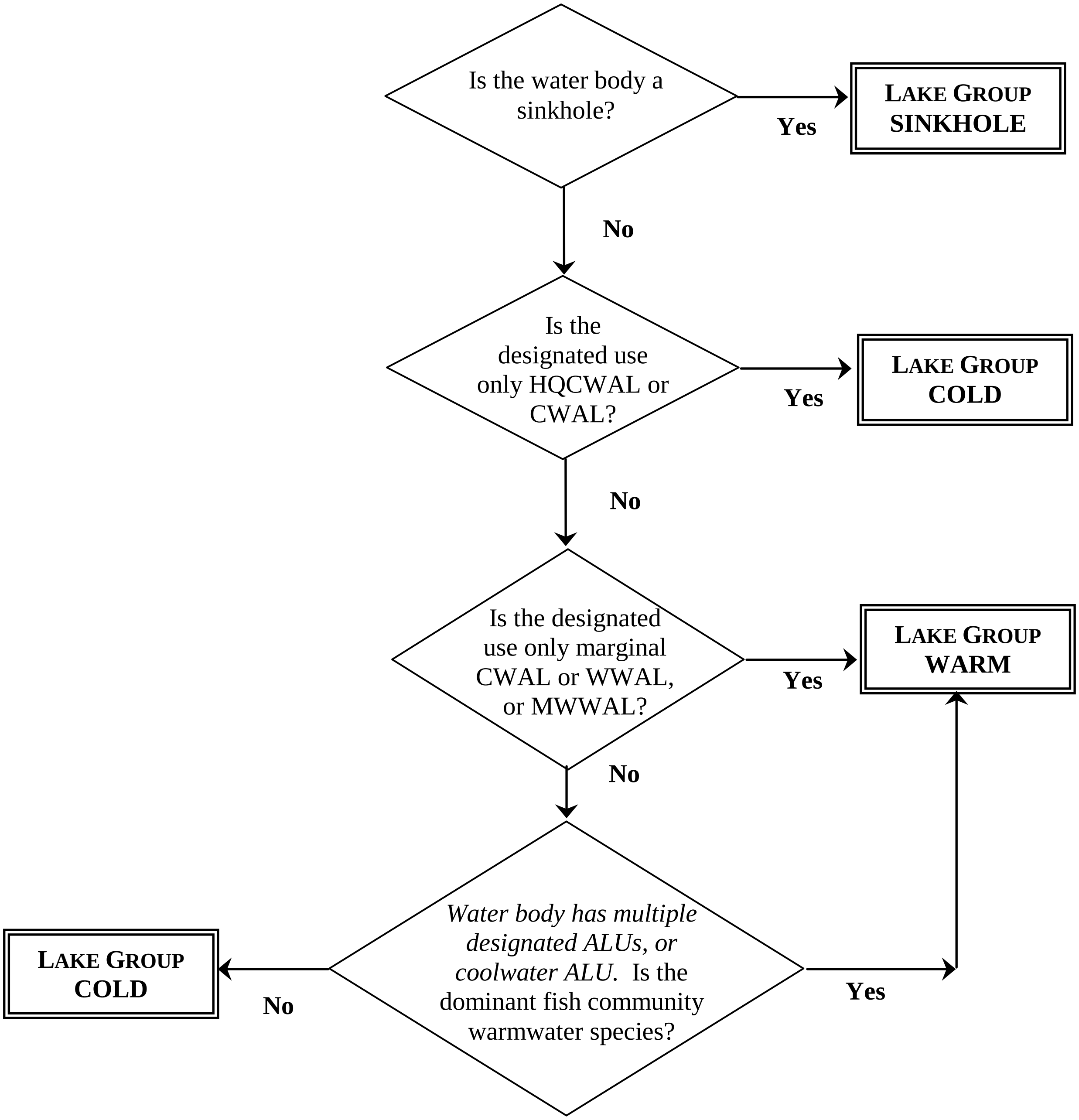

Figure 1. Generalized flowchart for determining lake group assignments

Table 1. Lake group assignments for evaluating TN, TP, algal biomass, and Secchi depth

Reservoir or Lake	Designated Aquatic Life Use	Assigned Lake Group
Abiquiu Reservoir	CWAL/WWAL	COLD
Bill Evans Lake	CoolWAL	WARM
Charette lakes	CWAL/WWAL	WARM
Clayton Lake	CoolWAL	WARM
Jackson Lake	CoolWAL	WARM
Lake Farmington	CWAL/WWAL	WARM
Monastery Lake	CoolWAL	COLD
Navajo Reservoir	CWAL/WWAL	COLD
Quemado Lake	CoolWAL	WARM
Ramah Lake	CWAL/WWAL	WARM
Santa Rosa Reservoir	CoolWAL	WARM
Springer Lake	CoolWAL	WARM
Storrie Lake	CWAL/WWAL	WARM

Potential nutrient enrichment indicators for TN, TP, algal biomass, and Secchi depth were collated from SWQB analyses, other state agency examples, or published literature. The indicators and respective threshold values selected for New Mexico lakes, reservoirs, and sinkholes are listed in Table 2. This selection was based on best professional judgment with respect to New Mexico's ecoregions. Additional information on all of the candidate thresholds is provided in Table 3.

Table 2. Nutrient-related impairment threshold values for New Mexico's lakes and reservoirs

	CAUSAL VARIABLES		RESPONSE VARIABLES			
Lake Group	**TP (mg/L)**	**TN (mg/L)**	**Secchi depth (m)**	**Chl-a (µg/L)**	**% Cyano-bacteria[a]**	**DO concentration[g] (mg/L)**
COLD	≤ 0.03 [b]	≤ 0.9 [c]	≥ 2.0 [b]	≤ 7.5 [b]	≤ 38% [c]	*See NMAC for applicable DO criterion*
WARM	≤ 0.04 [c]	≤ 1.4 [c]	≥ 1.2 [d]	≤ 11 [d]	≤ 38% [c]	
SINKHOLE	≤ 0.025 [e]	≤ 1.42 [e]	≥ 4.0 [f]	≤ 3.5 [f]	-	

a. *The cyanobacteria thresholds are expressed as a percentage of the total algae count.*
b. *Boundary between mesotrophic and eutrophic lakes (Nürnberg 1996).*
c. *Threshold values were derived from changepoint and regression tree analyses of water quality data from New Mexico (Scott and Haggard 2011).*
d. *Thresholds for Kansas Central Plains & SW Tablelands (Dodds 2006).*
e. *75th percentile of NM sinkhole lake data.*
f. *Thresholds between oligotrophic and mesotrophic lakes (Nürnberg 1996).*
g. *DO criteria are based on the designated aquatic life use(s) of the lake as assigned in Subsection H of 20.6.4.900 NMAC.*

Table 3. Candidate impairment thresholds from SWQB analyses and literature review

	CAUSAL VARIABLES		RESPONSE VARIABLES			SOURCE	
Lake Group	**TP (mg/L)**	**TN (mg/L)**	**Secchi Depth (m)**	**Chl-a^ (µg/L)**	**% Cyano-bacteria**	**Organization/ Author**	**Method of threshold derivation**
COLD candidate thresholds							
NM Coldwater ALU	0.03	0.5	1.5	2.3	-	NMED SWQB	Median of lake group
NM Coldwater ALU	-	-	3	6	21%	NMED SWQB	75th percentile of lake group
NM Coldwater ALU	0.04	0.9	-	-	38%	Scott and Haggard (2011)	Changepoint analysis
ID Mountain	0.015	0.28	-	1.8		ID DEQ	75th percentile of reference
AZ Coldwater	0.70	1.2	1.5-2.0	5-15	>50%	Arizona DEQ	AZ trophic index
mesotrophic-eutrophic boundary	0.030	0.65	2	7.5	-	Nürnberg (1996)	Literature review
WARM candidate thresholds							
Warmwater ALU	0.04	0.6	1	3.2	-	NMED SWQB	Median of lake group
Warmwater ALU	-	-	1.8	10	31%	NMED SWQB	75th percentile of lake group
Warmwater ALU	0.04	1.41	-	-	38%	Scott and Haggard (2011)	Changepoint analysis
ID Xeric	0.048	0.514	-	7.79	-	ID DEQ	75th percentile of reference
AZ Warmwater	0.13	1.7	0.8-1.0	25-40	>50%	Arizona DEQ	AZ trophic index
KS Central Plains & SW Tablelands	0.044	0.70	1.2	11	-	KSU & KS Dept. of Health & Env.	Median of best 1/3
SINKHOLE candidate thresholds							
Sinkhole lakes	0.025	1.42	6	-	-	NMED SWQB	75th percentile of sinkhole lakes
oligotrophic-mesotrophic boundary	0.01	0.35	4	3.5	-	Nürnberg (1996)	Literature review

NOTES: TP = total phosphorus; TN = total nitrogen; chl-a = chlorophyll *a*, mg/L = milligrams per liter; m = meter; µg/L = micrograms per liter

3.0. Assessment Procedures

This assessment procedure will only be conducted for lakes or reservoirs where the full suite of parameters was monitored. The following parameters are used as indicators in the assessment: nutrient concentrations (TP and TN), Secchi depth, algal biomass, and DO (grab or in-situ). The interpretation for each set of indicators is given below.

1. **Total Nitrogen (TN) and Total Phosphorus (TP) Concentrations**

Collate available TN and TP data. Compare the TN or TP concentration to the threshold values in Table 2, or to segment-specific TN or TP criteria in 20.6.4.98 – 20.6.4.899 NMAC if available. The information in Table 4 is used to interpret TN and TP data to determine if enrichment is indicated.

Table 4. Interpreting nutrient data

TYPE OF DATA	DOES NOT INDICATE ENRICHMENT	INDICATES ENRICHMENT	NOTES
•**Nutrients** (TN or TP) **A)** 1 to 10 samples **B**) >10 samples	**A**) No more than one exceedence of the threshold value. **B**) Threshold value exceeded in < 10% of measurements.	**A**) More than one exceedence of the threshold value. **B**) Threshold value exceeded in ≥ 10% of measurements.	Applicable thresholds are found in Table 2.

2. **Secchi Depth**

Secchi depth is a measure of water clarity. Higher Secchi depth measurements indicate clearer water, whereas lower readings indicate turbid or colored water. Clarity varies seasonally and is affected by algae, soil particles, and other materials suspended in the water. Consequently, Secchi depth can be used as an indicator of algal abundance and general lake productivity; however, high concentrations of non-algal suspended materials such as clay or organic matter can influence turbidity and skew the relationship between nutrients and chlorophyll production (Lee 1995). Since non-algal turbidity is a prominent characteristic of many impoundments in arid Western States (EPA 2000), Secchi depth will be treated cautiously and will need other supporting indicators to lead to an impairment (i.e., non-support) determination. This is because Secchi disk can be influenced by factors other than algae as mentioned above, which are influenced by weather (i.e., rain, strong winds) in the days before sampling as well as tributary input. The information in Table 5 is used to interpret Secchi depth and to determine if enrichment is indicated.

Table 5. Interpreting Secchi depth data

TYPE OF DATA	DOES NOT INDICATE ENRICHMENT	INDICATES ENRICHMENT	NOTES
•**Secchi depth**			
A) 1 to 10 samples	**A**) No more than one excursion of the threshold value.	**A**) More than one excursion of the threshold value.	Applicable thresholds are found in Table 2.
B) >10 samples	**B**) Threshold value excursions in < 10% of measurements.	**B**) Threshold value excursions in ≥ 10% of measurements.	

3. Algal Biomass

In lakes and reservoirs, phytoplankton production and biomass are useful parameters in monitoring changes in water quality. Chlorophyll *a* concentration is used as a surrogate for algal biomass and is generally the most appropriate variable to monitor (USEPA 2000). Chlorophyll *a* levels along with Secchi depths and TP are the measurements most commonly used to characterize the trophic status of lakes and reservoirs

Cyanobacteria (sometimes called blue-green algae) can be toxic under certain conditions and are considered nuisance species. The dominance of cyanobacteria and probability of toxic algal blooms increases with eutrophication (Dodds 2006), so the proportion of these taxa can be a useful indicator to evaluate nutrient loading and nuisance algal growth. The cyanobacteria thresholds are expressed as a percentage of the total algae count and are intended to identify blue-green dominance. The information in Table 6 is used to interpret data from algal biomass samples and to determine if enrichment is indicated.

Table 6. Interpreting algal biomass data

TYPE OF DATA	DOES NOT INDICATE ENRICHMENT	INDICATES ENRICHMENT	NOTES
•**Algal Biomass** (chlorophyll *a* or cyanobacteria)			
A) 1 sample	A) Chl-*a* concentration or cyanobacteria percentage is less than the applicable threshold value.	A) Chl-*a* concentration or cyanobacteria percentage is greater than the applicable threshold value.	Applicable threshold values for chlorophyll *a* are found in Table 2.
B) ≥2 samples	B) Exceedence rate ≤ 10% of measurements, or one or no exceedences of the applicable threshold value.	B) Exceedence rate > 10% of measurements with at least two exceedences of the applicable threshold value.	

4. DO Grab Data

Dissolved oxygen criteria are based on the designated aquatic life use(s) of as detailed in Subsection H of 20.6.4.900 NMAC. DO measurements taken at intervals are averaged for the epilimnion, or in the absence of an epilimnion, for the upper one-third of the water column of the lake to determine attainment of DO criteria. DO data are assessed according to the *Dissolved Oxygen Assessment Protocol* appendix of the most recent SWQB Assessment Protocols (available at: http://www.nmenv.state.nm.us/swqb/protocols/). The information in Table 8 is used to interpret DO data and to determine if enrichment is indicated.

Table 7. Criteria for dissolved oxygen concentration (per 20.6.4.900 NMAC)

Aquatic Life Use	DO Criterion*
High Quality Coldwater Coldwater Marginal Coldwater	6.0 mg/L
Coolwater Warmwater Marginal Warmwater	5.0 mg/L

NOTES: *In addition, if percent saturation is concurrently measured and is greater than or equal to 90%, there is no noted excursion of the DO criterion regardless of concentration.

Table 8. Interpreting DO data

TYPE OF DATA	DOES NOT INDICATE ENRICHMENT	INDICATES ENRICHMENT	NOTES
• **Instantaneous (grab) DO data**	DO is “Fully Supporting” according to the *Dissolved Oxygen Assessment Protocol.*	DO is “Not Supporting” according to the *Dissolved Oxygen Assessment Protocol.*	See 20.6.4.14 NMAC Subsection C Paragraph (3) for additional information regarding lake sampling.

ANALYSIS AND INTERPRETATION:

The threshold values selected for New Mexico lakes, reservoirs, and sinkholes listed in Table 2 are applied in a weight-of-evidence approach to assess data collected at the deep station. Compare each indicator to the associated impairment threshold using Tables 4 – 8 to determine which variables indicate potential nutrient enrichment. Indicators of nutrient concentrations (TP and TN) are considered causal variables. Secchi depth, algal biomass and DO indicators are considered response variables. A lake or reservoir is **Fully Supporting** with respect to New Mexico’s narrative nutrient standard if (1) one or none of the variables (causal or response variables) indicate enrichment, or (2) total nitrogen or total phosphorus indicate enrichment, but there was no indication of a biological response to elevated nutrients (i.e., no response variables indicate enrichment). A lake or reservoir is **Not Supporting** if (1) *at least* one causal variable and one response variable indicate enrichment, or (2) if chlorophyll *a* and another response variable (Secchi depth, % cyanobacteria, or DO) indicate enrichment. This second scenario is to account for situations in which the lake is receiving a significant nutrient load, but the nutrients are quickly being assimilated into the biomass of the lake, hence low nutrient concentrations but undesirable effects (refer to example "Lake Two" in Table 9).

Figure 2 provides a generalized flowchart of the assessment procedure. Table 9 provides some examples of how nutrient assessments will be conducted following these rules.

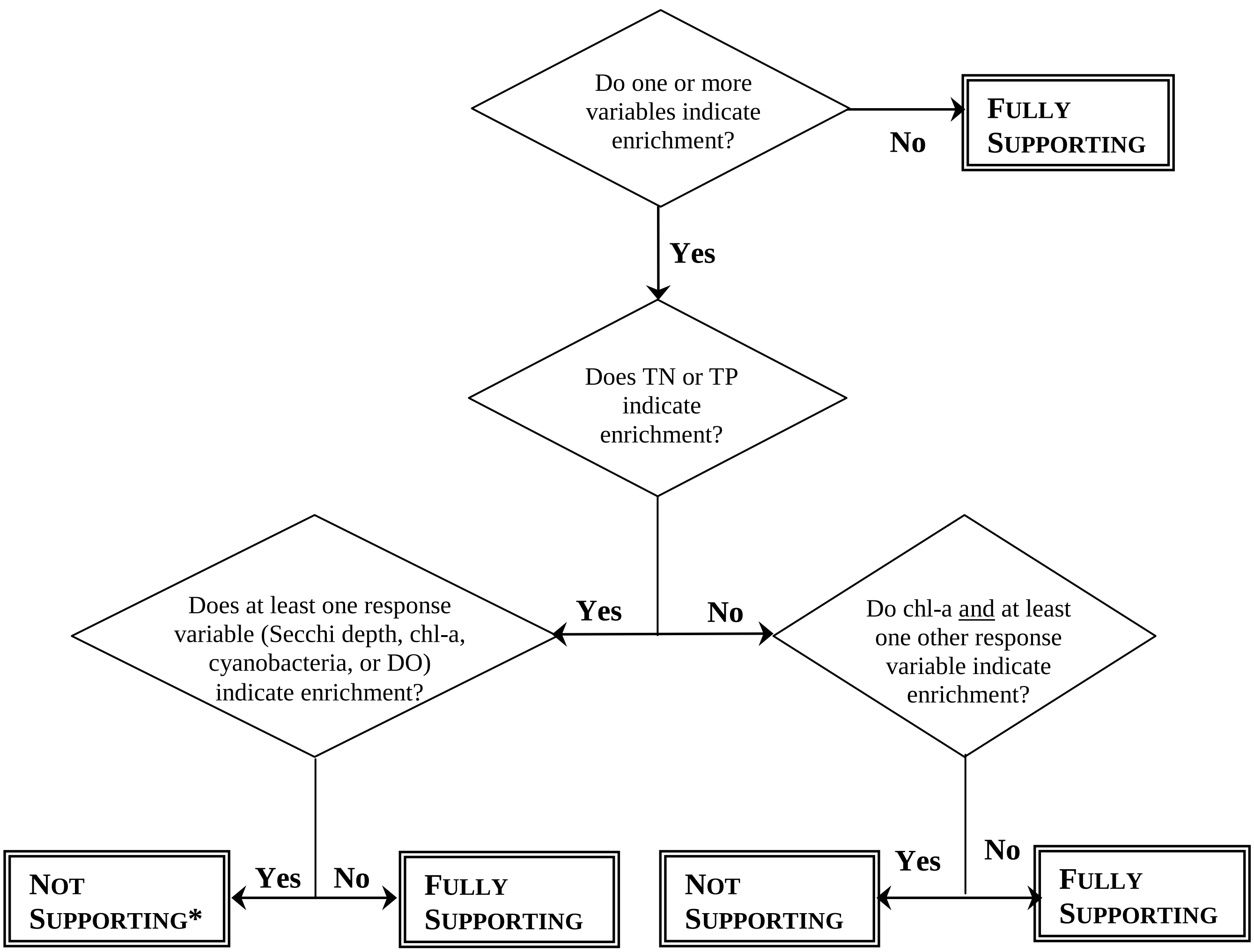

Figure 2. Generalized flowchart for determining nutrient impairment in NM lakes and reservoirs

NOTES: Enrichment is determined using Tables 4-8. * If *only* Secchi depth violates, evaluate other data (e.g. Forel Ule color, trophic state index) to determine if low Secchi depth is the result of elevated levels of non-algal particulates (refer to example "Lake Five" in Table 9).

Table 9. Examples of lake and reservoir assessments

Indicators	Lake One *COLD*	Lake Two *COLD*	Lake Three *WARM*	Lake Four *WARM*	Lake Five *SINKHOLE*
TP (mg/L)	0.015	0.03	0.02	**0.051**	**0.032**
TN (mg/L)	0.249	0.45	0.29	**2.06**	**2.69**
Secchi depth (m)	**1.5**	**1.5**	1.3	1.95	**2**
Chlorophyll *a* (µg/L)	0.28	**15.4**	**12**	**23**	0.4
% Cyanobacteria	0	**50**	24	5	7.4
DO attains the criteria	Yes	Yes	Yes	Yes	Yes
Support Determination	Full Support	**Non Support**	Full Support	**Non Support**	Undetermined*****

NOTES: Actual lake nutrient assessments will typically have two to eight values for each indicator. Tables 3 – 8 are used to help interpret data. Excursions of the threshold values are **bolded and shaded**.

* Need to evaluate other data (e.g. Forel Ule color, trophic state index) to determine if low Secchi depth is the result of elevated levels of non-algal particulates.

REVISION HISTORY:

2014 listing cycle – Pre Public Comment: Original. **Post Public Comment**: Minor edits and clarification to various sections, including DO assessment procedures and lake groups.

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